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Company:	USEPA, Chief Office of Pacific Island and Native American Programs	Company:	CH2M HILL
City/State:		Job No.:	PDX30702.PA.NP
Office No.:	415 744-1599	Subject:	Response to Comments from USEPA on Zone of Mixing Application
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REMARKS: Sorry this was not sent to you Friday - but there were some changes required. FAX of this text has also been sent to Doug Linden. Sheila Wiegman is off-island at USEPA office in Hawaii - can you or Mr. Linden see that she gets a copy prior to our meeting on Wednesday? Thank you -

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MEMORANDUM CH2M HILL

TO: Doug Liden/USEPA
(your reference: W-5-1)

COPIES: Sheila Wiegman/ASEPA
Pati Faiai/ASEPA
Norman Lovelace/USEPA
Norman Wei/StarKist Seafood
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FROM: Steve Costa/CH2M HILL

DATE: 10 November 1991

SUBJECT: Response to USEPA Comments on Zone of Mixing Application

PROJECT: PDX30702.PA.MZ

PURPOSE

The U.S. Environmental Protection Agency, through Limo-Tech, Inc., requested Dr. Steven J. Wright of the University of Michigan to review the Zone of Mixing Application for the Joint Cannery Outfall in Pago Pago Harbor, American Samoa. The purpose of this memorandum is to respond to Dr. Wright's comments, to clarify a few points on which Dr. Wright's comments were based, and to present our response to Limno-Tech's overall conclusions concerning the Zone of Mixing Application.

We have responded to Dr. Wright's comments point-by-point in the section indicated as "Response to Specific Comments" below. Following the section on specific responses we have addressed the overall conclusions presented by Limo-Tech in the "Response to General Comments" section. We then present our conclusions.

SUMMARY

We found Dr. Wright's review to be generally useful. However, there are some points concerning his interpretation of our analysis that require clarification. Because of some misinterpretation of our methods of analysis, Dr. Wright concluded that the attainment of water quality standards with the proposed zone of mixing and present loading conditions is marginal. He recommends additional analysis. We disagree with Dr. Wright's conclusions for the reasons described below.

RESPONSE TO SPECIFIC COMMENTS

A copy of Dr. Wright's review is attached (Attachment 1) and comments to which responses are provided in this memorandum are indicated in the margin of his review, and correspond to the numbering system below.

RESPONSES TO COMMENTS ON WASTEFIELD TRANSPORT MODEL

[1] As described in Chapter 2 of the Feasibility Study (CH2M HILL 1991a), the tidal and freshwater flows are very small. Most of the transport of water column constituents is driven by random and "quasi"-random processes. The most important of these is wind driven transport which is treated as a random process and represented as included in the eddy diffusion coefficient. Therefore, the major transport mechanism provided for by the model is gradient generated diffusive processes. The dispersion (or eddy diffusion) coefficients account for more than mixing processes on time scales that are small with respect to tidal periods.

Information presented in Chapter 2 also indicates that there are identifiable long term average currents (wind driven) in the harbor. Location of the diffuser in a favorable location will enhance the flushing and the use of a diffusion coefficient based on harbor-wide data will provide results that predict higher than expected concentrations (conservative predictions).

[2] The discharge from the Utulei Outfall was included in the model as a point source using the loadings described in the Waste Load Allocation Study (HRI 1989). All other point sources are small and are included in the nonpoint source inputs. We apologize for not making this point clearly in the model descriptions. Examples of input and output are provided in Appendix C of the Feasibility Study. We apologize for any confusion that might have arisen because the examples of I/O files are incorrectly described. On page C1-5 the last of items listed for the job control file are in error. The cells, flows, and loadings for point sources are not found in this file, but rather in the hydrodynamics and water quality/geometry files. In addition the input file examples are not necessarily consistent with the output file examples.

In the actual model runs the Utulei Outfall effluent was discharged to cell {I,J = 3,7} as shown on page C1-17. Total nitrogen (TN) loadings were taken as 59 kg/day and total phosphorous (TP) loadings as 27 kg/day. The effect of these loadings in this location is illustrated in Figure C3-16 and C3-32 for TN and TP, respectively. These figures represent the effect of the Utulei Outfall and all nonpoint sources (including small point sources). For an assumed oceanic background the TN is elevated above background by only a few percent.

[3] We agree that the use of a more sophisticated model is not indicated based on the available data. In addition the data requirements for a more complex model would be, because of the nature of the transport process and driving forces, extensive. However, it should be noted that the situation, as described below, results in conservative predictions for discharge from the proposed diffuser site. The following points are important with respect to depth averaging:

- Past, and present, concentrations of nutrients in the harbor result from a surfacing plume

- The depths where concentrations were measured are surface, 70 feet (approximately) and bottom (HRI 1989)

- The primary density gradient is generally in the top 20 to 30 feet as described by the HRI data and the density gradient data used in the Feasibility Study (the system is approximated as a two layer system with a surface layer much thinner than the deep layer)

- An average of the three values (three depths) of nutrient concentrations will result in a depth average that is biased to the high side since there was no weighting factor applied and the highest (surface) values should have a relatively small weighting factor

- The diffusion constant based on calibration runs will therefore be smaller than it should be and the result will be a prediction based on artificially high depth averaged values reflecting apparently inhibited flushing of TN and TP from the harbor

- Future concentrations of nutrients will result from a generally trapped plume that will bias the depth averages less than for the case of a surfacing plume since the bottom layer occupies most of the water column

The model predictions for the outer harbor location are based on a model that underestimates flushing (low diffusion coefficient) and does not account for net current patterns as discussed in [1] above. The predicted depth averaged value is based on conservative approaches that would tend to predict high values. For the proposed diffuser location, the surface layer values of TN and TP will be somewhat lower than the depth average values predicted by the model.

RESPONSES TO COMMENTS ON INITIAL DILUTION MODEL

[4] UDKHDEN often predicts higher dilutions than other plume models in cases with currents, probably because the calculation of the curvature of the plume centerline tends to "delay" the attainment of surfacing or trapping (longer trajectories along the centerline). However, the situation is not straightforward. Figures 4-6 and 4-7 in the Feasibility Study present some model results for the outer harbor for three discharge depths and two discharge rates with all other variables held constant. These figures show the following:

- For zero current the dilutions predicted by the two models are consistent

- For zero current the predicted trapping depths are generally deeper (further below the surface) for UMERGE with the largest difference at the intermediate discharge depth (150 feet)

- For the 5 cm/sec case predicted dilutions are about the same for both models at a discharge depth of 100 feet

- For the 5 cm/sec case, at a discharge depth of 150 feet, dilutions predicted by UMERGE are about 60 percent of those predicted by UDKHDEN

- For the 5 cm/sec case predicted dilutions are about the same for both models at the high discharge rate but UMERGE predicts a dilution about 160 percent higher than UDKHDEN for the low discharge rate at a discharge depth of 200 feet

- For the 5 cm/sec case predicted trapping levels are somewhat higher for UDKHDEN at 100 feet, and somewhat higher for UMERGE at 150 feet

- For the 5 cm/sec case trapping level predictions, at a 200-foot discharge depth, are comparable for both models for the high flow rates but for the low discharge case UMERGE predicts a shallower depth (this is consistent with the higher dilution)

The differences in the models do not appear to be (solely) related to ambient current but rather more related to the ambient density and density gradients in combination with the ambient velocity (additional comparisons between the two models are provided in Appendix D of the Feasibility Study). Comparison of runs for the inner harbor conditions show good agreement between the models.

The final diffuser configuration is in about 180 feet of water and the effluent flow rates will vary considerably. Results from UDKHDEN appear to give more consistent results over a range of effluent discharge rates in terms of trends. At the higher effluent discharge rates and a 5 cm/sec ambient current UDKHDEN predicts the same or lower dilutions as UMERGE. It should also be noted that the 5 cm/sec ambient velocity is about two orders of magnitude lower than the discharge velocity through the ports. It is not a particularly rapid ambient current, and other factors are probably as important with respect to the differences in model predictions for the cases considered here.

what conditions did wright run?

Dr. Wright apparently did not run his modified UDKHDEN code for all of the same conditions we considered. For the cases he did run, his modified program appears to predict dilutions much lower than UMERGE for the 5 cm/sec case (approximately 1/3 of our unmodified UDKHDEN results). We feel this would be a unreasonably conservative prediction.

[5] All of the results used for the definition of the mixing zone are based on zero velocity. Therefore, as Dr. Wright points out, the choice of models is academic with respect to this point. However, our runs for non-zero velocities were done to get a feeling for the degree of conservatism in assuming a zero current situation. We consider a small current speed (about 5 cm/sec) to be a typically realistic condition. Our results, using either UDKHDEN or UMERGE indicate that the use of the zero velocity assumption is quite conservative compared to the more realistic 5 cm/sec assumption.

Based on UDKHDEN, and for conditions approximating the final diffuser location, the initial dilution at 5 cm/sec will be approximately 5 times the initial dilution at zero current (see tables in the Zone of Mixing Technical Memorandum, CH2M HILL, 1991b). Based on our experience comparing UDKHDEN with field data (dye studies), the model underestimates dilution at ambient velocities under 25 cm/sec and over 200 cm/sec. Between these extremes UDKHDEN has not appeared, in our experience, to overestimate dilution but has provided predictions fairly close to observations. Obviously, model and field data comparison is difficult and this is an area that needs more research. However, our professional judgement is to choose UDKHDEN, to assess the degree of conservatism, based on our experience and all of the factors discussed in [4] above.

If Dr. Wright's conclusion that UDKHDEN is predicting initial dilutions about 3 times too high at 5 cm/sec is accepted then our factor of conservatism is about 2 rather than 5. This, added to the known conservative predictions of any of the models at zero current, still results in a very conservative approach.

[6] The equation discussed by Dr. Wright relates the required dilution (S) to meet the water quality standard concentration (C_s) under conditions of ambient concentration (C_a) for a given effluent concentration (C_e) and is given by:

$$S\ (C_a - C_s) = (C_a - C_e).$$

Dr. Wright states that:

> *"There is a statement that C_a ought to be taken as the concentration outside the harbor, 0.12 mg/l for total nitrogen. However, this is the concentration of the water entrained into the plumes by definition and therefore must be the local concentration (at the location of the diffuser) predicted by the wastefield transport model or some similar approach.*

He implies that we used the background value of 0.12 mg/l for TN and .0125 mg/l for TP as C_a in order to calculate the concentration at the end of initial dilution during the development of the mixing zone dimensions required. This is not the case and there appears to be some confusion or misinterpretation which we hope to clarify by considering the following points (underlines and bold added for emphasis):

- On page 4-12, Chapter 4 of the Feasibility Study Report we state:

  > "The closer the values of the standard and the ambient concentrations, the more difficult it is to meet the standards, that is the higher the initial dilution must be to meet the water quality standards. **For example, if** the ambient TN concentration is the ocean background **(the outfall is beyond the harbor entrance)** of 0.12 mg/l and the water quality standard is 0.200 mg/l, the required initial dilution to meet the standard, ...

  This clearly refers to a hypothetical "best case" and it is clearly understood that such a condition (C_a = 0.012 mg/l) can only be attained outside the harbor.

- On the same page as above we further state:

  > "Moving the discharge **into the harbor where the ambient concentrations are higher** leads to even higher, and unattainable, initial dilution requirements.

  This statement clearly demonstrates our recognition that 0.12 mg/l is not appropriate for use as Ca within the harbor.

- On page 4-13 of the Feasibility Study Report we state:

  > "For the middle and outer harbor ... the minimum initial dilution expected ... is over 150:1. For an effluent concentration of TN of 100 mg/l, the dilution at the end of initial dilution process is 0.87 mg/l **based on ambient concentration of 0.200 mg/l.**

  If 0.12 mg/l had been used in the above equation for C_a the calculated concentration would have been 0.79 mg/l rather than 0.87 mg/l. This example actually represents a worst case scenario for initial dilution with the ambient concentration equal to the standard. We clearly recognized in our permit application and supporting documentation that the use of 0.12 mg/l as C_a is inappropriate inside the harbor.

- On pages 24 and 25 of the Zone of Mixing Technical Memorandum the first two points above are restated in the same manner. Please note that there are typographical errors in the equations on pages 24 and 25: on page 24, in the right hand term Cs should be Ca, and on page 25, in the left hand term 0.200 should be 0.120.

The points listed above were presented in a discussion of what initial dilutions would be required to meet the water quality standards accounting only for initial dilution. It must be remembered that the S in the equation above is the required total dilution, which includes initial dilution, required to meet the standard under given conditions.

We obviously recognized in the zone of mixing application the points made by Dr. Wright concerning the need to use the ambient concentration at the location of the diffuser and that these values are derived from the long term waste loadings and the location of the diffuser. Dr. Wright apparently misread our description which we had simplified, maybe too much, for the discussion in the reports.

[7] As described above it was recognized in the zone of mixing application that it is inappropriate to use an ambient concentration equal to the background concentration at the diffuser location. The calculations summarized in Table 15 indicate that we recognize the need to use the local ambient concentration to calculate the required dilution to meet the standard. For example consider the first (left hand) column in Table 15A on Page 29 of the Mixing Zone Technical Memorandum:

- Effluent Concentration = 74.9 mg/l
- Ambient Concentration = 0.165 mg/l
- Standard Concentration = 0.200 mg/l
- Required dilution = (0.165-74.9)/(0.165-0.200) = 2135

The required total dilution to meet the standard is 2135. This is based on using the wastefield model predicted ambient concentration of 0.165 mg/l not the background concentration of 0.12 mg/l which would result in a required dilution of 934 (about half the actual required value, as pointed out by Dr. Wright).

In this case the available (model predicted) initial dilution was 395. This means that a subsequent dilution of 5.4 will be required to meet water quality standards under all of the assumptions used in the analysis, which are conservative.

Dr. Wright implies that the permit application is based on meeting the standards using initial dilution only. This implication is not the case. Again, the equation above refers to the total required dilution, only a part of which is accounted for by initial dilution. Some of the discussions presented by Dr. Wright concerning the possibility of meeting the standards with only initial dilution appear to have resulted from his misreading of the permit application and supporting documents. However, the information presented in our reports clearly indicate that meeting the standards using initial dilution only is not possible for the very reasons stated by Dr. Wright.

[8] For reasons described under our response to comment [3] above we do not think there is justification for lowering the model predicted ambient concentration as Dr. Wright suggested. This would reduce the predicted required mixing zone size. However, this certainly would not be a conservative approach. With the diffuser in 170 to 180 feet of water and a trapped plume, the ambient concentrations at depth may actually be somewhat higher than the depth-averaged values. However, this is not of concern and would have only a small effect on the final calculations. Our approach was to, given a choice, use a somewhat higher value for ambient concentration than predicted.

RESPONSE TO COMMENTS ON FAR-FIELD TRANSPORT MODEL

[9] The model permits three options on length scale dependence: 0, 1, or 4/3 power. The linear option (first power on length) was used for this case. This is a standard assumption for an semi-enclosed body of water with a nearby shoreline. A case for the "four thirds" power could be made since it is not intended to extend the calculations to a distance where the shoreline would have a major impact. However, given the proximity of shallow water on the reef we felt that the linear assumption was more appropriate. In any event, use of the "four-thirds law" would not substantially change the results. ?

[10] The use of this model does lead to conservative results for the reasons stated in the Technical Memorandum. In addition the entire approach of using a subsequent dilution model is more conservative than the general approach to mixing zone determination. In most studies farfield, nearfield, and initial dilution calculations are done. In this context a farfield calculation will be done to set average or steady state boundary conditions for the nearfield. This is analogous to our use of a constant background concentration at the entrance to the harbor. Then a nearfield model will be used to determine the ambient concentrations in the vicinity of the diffuser. This is essentially our application of the wastefield transport model (which can alternatively be thought of as serving as both farfield and nearfield models). Then initial dilution models will be used accounting for the ambient concentrations in the nearfield (as we did).

Usually the initial dilution model (accounting for ambient conditions) will be used to determine the zone of initial dilution (ZID) and the nearfield results will be used to determine the size of the zone of mixing. In both the feasibility study and the Zone of Mixing Technical Memorandum there is a discussion of the use of the wastefield transport model to estimate the required size of the zone of mixing. We decided to take the additional step and use a subsequent dilution model to account for the transition between the nearfield and the ZID and to provide a check on the use of the wastefield transport model. The subsequent dilution model effectively verifies the results concerning mixing zone size based on the wastefield transport model. The subsequent dilution model is a redundant check on the conclusions about required size of the mixing zone and that conclusion does not depend on the subsequent dilution model.

For the reasons stated in the text of the Technical Memorandum (page 26) we elected to apply a subsequent dilution model. The model is called a farfield dilution model to be consistent with the description in the documentation referenced. In the context of our application the term subsequent dilution is probably more appropriate since we do not extend the model results into what would be considered the farfield. The use of a subsequent dilution model superimposed on a nearfield description is a <u>conservative approach</u> relative to typical mixing zone studies.

We have used the Brooks formulation routinely and are well aware of the implications and limitations of the model. We do not claim that lateral diffusion must balance horizontal advection as stated by Dr. Wright. We never make that statement. We recognize the limitations of the model at low velocities since there is no longitudinal diffusion term in the model. To simulate a zero current condition with this model we have set the current speed so that the longitudinal transport term (advective) is of the same size as the lateral transport term (diffusive). We did not use 5 cm/sec but rather 0.05 cm/sec as a current speed to simulate the zero current condition (see page 27 of the Technical Memorandum and page 4-13 of the feasibility study). Actually, a 5 cm/sec current would result in lower predicted dilutions at a given distance than the 0.05 cm/sec case. However, this would be adequately compensated for by the higher initial dilutions under such a condition.

[11] Dr. Wright brings up an interesting, and often overlooked point. We agree that mass conservation must be satisfied for realistic solutions. The subsequent dilution model is based on a mathematical singularity in the form of a "line source" of constant initial concentration and does not consider the effluent or constituent mass flow. To provide for physically realistic application the effluent flow rate must be equal to the flow of fluid past the source: as indicated in the comment, the flow through the source area must be sufficient to account for the effluent flow from the diffuser. This condition must also be met for the flux of any constituent. It is true that the subsequent dilution model does not meet this criteria in the neighborhood (in the mathematical sense) of the diffuser. However, the model does meet the criteria at a reasonable distance from the diffuser. We conclude that it is reasonable to use the model as formulated to verify the mixing zone dimensions required as shown by the following calculations:

<u>CONDITION CLOSE TO THE DIFFUSER</u>

- Consider an average effluent rate of 2.4 mgd which is equivalent to

  2,400,000/7.5 = 320,000 cubic feet per day

  320,000/86,400 = 3.7 cfs

- The initial mixing is by entrainment. The effluent flow is physically mixed with ambient water and the diluted waste stream or plume has a flow rate defined in terms of dilution (S). Consider an initial dilution of about 350, then the flow rate of the plume at the end of initial dilution is

  (3.7 cfs)x(350) = 1295 cfs

- The flow area through which this flow must pass under, the assumptions of the subsequent dilution model as it is formulated, is 200 feet wide. The depth is on the order of the distance between the trapping depth and the maximum rise depth of the plume, which is about 13 meters (this is close to the plume width, which is reasonable - see results in Appendix A of the Technical Memorandum)

  200 x 42.65 = 8,530 square feet

- Therefore the velocity that the effluent plume must have across this area to maintain mass conservation is

  1295/8,530 = 0.152 feet per second = 4.6 cm/sec

- The argument could be made that the effluent plume should be considered moving in both directions away from the diffuser (flow area 400 feet wide) or radially outward from the diffuser (flow area 634 feet wide). However, even with this adjustment the subsequent dilution model obviously <u>is not applicable very close to the diffuser.</u>

<u>CONDITION AT A DISTANCE FROM THE DIFFUSER</u>

- Consider the same average effluent rate of 2.4 mgd = 3.7 cfs

- The initial mixing is by entrainment. However, the subsequent dilution is by diffusion and the zero ambient current speed assumption is equivalent to assuming that the kinetic energy represented by the initial velocity of the effluent plume is dissipated in turbulent eddies in the receiving water. The conservation of mass still requires that, through any control volume around the diffuser, an outward flow of 3.7 cfs must be taking place.

- Under our formulation of a line source with a radial spreading front the flow area through which this flow must pass at the limit of the proposed mixing zone size is approximately 2,000 feet wide. The depth is on the order of the water depth which averages over 100 feet in the mixing zone area which results in a flow area of

  2,000 x 100 = 200,000 square feet

- Therefore the velocity that the effluent plume must have to maintain mass conservation is

  3.7/200,000 = 0.0000185 feet per second = 0.00056 cm/sec

- The argument could be made that the kinetic energy is not all dissipated very close to the diffuser. However, during many dye-dispersion field experiments our personal observations and measurements of surfacing plumes at times of slack water clearly indicate that the kinetic energy (velocity) in the plume dissipates rapidly. Our observations in the field indicate that the assumption of nearly total dissipation within a few plume diameters is reasonable. The subsequent dilution model obviously is <u>applicable beginning a short distance from the diffuser.</u>

Our use of 0.05 cm/sec to simulate zero current conditions appears physically reasonable, and does not violate mass conservation, for the characteristics of the system we are considering. If the extreme case were considered, and all kinetic energy was assumed dissipated immediately, then the current across the area at the line source would be 0.013 cm/sec. A current speed of 0.013 cm/sec in the subsequent dilution model (CDIFF) gives unrealistic results (an example run is given in Attachment 2). The basic problem with the model is not mass conservation but the difference in the transport mechanisms allowed in the longitudinal and lateral directions. It is not generally applicable at low speeds. We are purposely manipulating it to simulate a zero current condition. The approach is not rigorous but is a reasonable approximation. We would tend to agree that low current cases cannot be realistically modeled with the Brooks formulation. But, what we have done is a somewhat different application.

We do not completely follow Dr. Wrights reasoning for setting the <u>ambient</u> velocity at 5 cm/sec: we did not use 5 cm/sec, nor does an analysis of required current speeds indicate that 5 cm/sec is necessary (except very close to the diffuser). However the subsequent dilution model does appear to be applicable at this current speed. Attachment 2 to this memorandum provides examples of CDIFF runs at 5 cm/sec and for both the linear and 4/3-law assumptions.

The total flux of nitrogen or phosphorous and the total flow of water through any control volume around the diffuser must (assuming a conservative substance with no sinks) equal the mass discharging from the diffuser. Dr. Wright's mass balance equation considers advective transport only, which may be a good approximation <u>only</u> very close to the diffuser. The model, and the physical system, under consideration includes both advective and diffusive transport terms. We suspect a transcription or typographical error in the equation and believe that the right hand term, assuming S is taken to be dilution and C_s the water quality standard concentration, should be SQ_eC_s. However, we believe the right hand term is not an appropriate description of the problem if the water quality standard is not met by initial dilution, since there is no consideration of diffusive transport whatsoever.

[12] As stated above, we agree that low current cases cannot be realistically modeled with the Brooks formulation. What we are did was a somewhat different application, and the technique is used to approximate a worst case condition, in what we believe is a conservative fashion.

[13] Again, we did not use 5 cm/sec as described above. If we did assume this was appropriate we would also use 5 cm/sec to calculate initial dilutions. On page 25 of the Technical Memorandum supporting the Zone of Mixing Application we do not state that near field dilutions of 875 to 1250 are required. We state that if the discharge is outside the harbor initial dilutions of 875 to 1250 would be required if the standard were to be achieved with initial dilution only. We further state that inside the harbor even higher dilutions are required. In Table 15 the required dilutions are presented for a variety of cases. The value suggested by Dr. Wright of 2000 (for TN) is actually lower, and less conservative, than our assessment of required dilutions as used in the analysis of mixing zone size.

[14] A subsequent dilution of 3-4 at 1300 feet for a current speed of 5 cm/sec appears reasonable. A model run for CDIFF at this current speed is provided in Attachment 2. We agree that this would require initial dilutions of 500 or more to meet water quality standards. Such dilutions are higher than predicted for trapped plumes at zero current speed. However, they are predicted for zero current speed at surfacing plume conditions (see Table 12, page 20 of the Mixing Zone Technical memorandum) and are predicted for a current speed of 5 cm/sec for the trapped plume (the above discussion of appropriate initial dilution models being considered, see for example Table 10 on page 17 of the Technical Memorandum). Please note that on Table 10 for the 2.0 mgd, 5 cm/sec case the dilutions, trapping levels, and plume widths are switched between lines 2 and 3 (4-inch, weak density gradient and 6-inch, strong density gradient). Therefore, the proposed mixing zone is consistent with both the zero current and the 5 cm/sec ambient current conditions.

Increases in future loading are adequately accounted for in our analysis as summarized in Table 15. This analysis was based entirely on a zero current speed assumption. The data presented indicates a current speed of, for example, 2.5 or 5 cm/sec applied to both initial and subsequent dilution would not change our conclusions as to mixing zone size and supportable loadings. We do not understand why an increase in loadings necessarily results in a decrease in initial dilution, as stated by Dr. Wright. Increased loadings may not result in comparable increased effluent rates. In addition, the diffuser has been designed with additional ports that will be blocked at installation but can be opened in the future if required. This design will accommodate increased effluent flows with no degradation in initial dilution. Table 15 in the Technical Memorandum indicates the potential for increased average and peak loading values to account for future growth. ?

[15] For the reasons stated above we strongly disagree that the attainment at the edge of the mixing zone is marginal, nor do we feel that any additional analysis is required for present or future loadings. We consider the analysis done to be conservative.

RESPONSE TO GENERAL COMMENTS

A copy of Limno-Tech's summary of Dr. Wright's review is attached (Attachment 1) and comments to which responses are provided in this memorandum are indicated in the margin of the summary, and correspond to the numbering system below.

[S1] The loading from the Utulei treatment plant were included as a point source in the model. All other sources were included in the nonpoint source terms. More detail is provided in the response to item [2] above.

[S2] UDKHDEN predictions under conditions of non-zero ambient currents are higher than the predictions of other EPA plume models. We do not think they are higher than expected conditions for relatively low speeds (like 5 cm/sec). However, the initial dilutions used to size the zone of mixing were based on zero current speed and the predictions agree well with UMERGE and Dr. Wright's modified UDKHDEN. This point is then academic unless it is desired to base the mixing zone size under the assumption of non-zero current speeds. Additional detail is provided in the responses to items [4] and [5] above.

[S3] Contrary to the comment the study <u>does not</u> assume that the ambient concentrations near the edge of the mixing zone are represented by concentrations outside the harbor. Actual (predicted) concentrations, which are higher than ocean background, are used and the determination of the required dilution does account for this effect. This conclusion is based on comments by Dr. Wright that are based on his misinterpretations of our procedure. This point is discussed in considerable detail in the responses to items [6], [7], [13], and others above.

[S4] We recognize that subsequent dilution (farfield) model is not appropriate for very low currents. However, it can be manipulated to simulate the condition of zero-current by appropriate choice of current speed. This approach is not standard but is formulated in a fashion that is consistent with the physics of the system. Our professional opinion is that the use of the model in refining the mixing zone dimensions, results in conservative predictions. More detail is provided in response to items [9], [10],[11], and [12] above.

[S5] Evidently the reviewers think that the proposed mixing zone size is considered "marginal" for present loadings. We disagree with the comment and believe it is based on misunderstandings and a cursory review of our analysis. There was no indication given by the reviewer of what additional "analysis of design criteria" is being referred to in his comments. The diffuser configuration has been optimized considering all factors. Movement of diffuser location will not substantially change the required mixing zone size. The only other alternatives involve lower loadings or larger mixing zones, neither of which we believe are necessary.

CONCLUSIONS

We appreciate the reviewers comments. However, we believe the conclusions of the reviewers were based on a review that was cursory in scope and effort. After addressing all of the comments the only issue is the use of CDIFF to simulate zero current condidtions for subsequent dilution calculations for this system. We understand the reluctance about manipulating and using CDIFF in a somewhat unconventional fashion for this system (but not for the reasons stated). As described above the consideration of subsequent dilution is not common in defining mixing zones and is usually not done. Given the environmental sensitivity of the nearby coral reefs we determined that the additional consideration was appropriate. During the analysis alternative ways of addressing the subsequent dilution problem were considered which were as follows:

- Do not consider subsequent dilution at all and simply use the wastefield transport model results to predict the required size of the mixing zone

- Do not consider subsequent dilution at all and use the wastefield transport model with a smaller grid size (about 200 feet) in the immediate vicinity of the diffuser with boundary conditions derived from the existing ("large grid") model results to predict the mixing zone size

- Use a more sophisticated model that provides a fully two dimensional (or three dimensional) description of the subsequent dilution due to eddy diffusion in all directions (CH2M HILL has developed a model, PT211, that will do such calculations)

We did not use and do not recommend any of these approaches. We believe, based on our experience and judgement that all of the alternative approaches would have resulted in a less conservative approach. In addition, the use of a smaller grid size or a more sophisticated model would be impossible to justify due to lack of field data for calibration. This would be a particularly severe problem for a model such as described in the last point above. The collection of such data is not feasible because of the amount (number of stations and variables) and length of time series (order of at least a few years) of data required.

It is our professional opinion that the analysis done supports the required zone of mixing location and size proposed in the permit application to American Samoa Environmental Quality Commission. It is also our professional judgement that the analysis was done in a conservative manner, addressing the protection of environmental resources and water quality with a reasonable and prudent factor of safety. We do not believe that any additional analysis is required.

REFERENCES

CH2M HILL. *Engineering and Environmental Feasibility Evaluation of Waste Disposal Alternatives.* Draft Final Report. Prepared for StarKist Samoa, Inc. February 1991a.

CH2M HILL. *Site-Specific Zone of Mixing Determination for the Joint Cannery Outfall Project: Pago Pago Harbor, American Samoa.* Technical Memorandum prepared for StarKist Samoa, Inc. and Samoa Packing Company. August 26, 1991b.

Hydro Resources International (HRI). *A Waste Load Allocation Study for Pago Pago Harbor, American Samoa.* Prepared for American Samoa Environmental Protection Agency. 1989.